ANIP

ARMY-NAVY INSTRUMENTATION PROGRAM

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ARMY-NAVY INSTRUMENTATION PROGRAM

ILLUSTRATED

NARRATIVE

FROM

THE FILM

CONTRACT Nonr 1076(00)

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SUMMARY

The Army-Navy Instrumentation Program (ANIP) was conceived in 1953 for the purpose of providing a new concept of flight data instrumentation which would make possible the optimum use of performance capability and true all weather operation of aircraft.

One of the objectives of ANIP was to unburden the pilot by providing carefully designed, artifically generated, more natural displays.

The concept as described in the following pages is seen to be applicable to many forms of man-machine systems. Developments of the long range program would appear to be applicable to surface vessels, submarines and ground vehicles as well as aircraft.

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This paper presents a concept and methodology for integrating man and machine. It will show what has been done and what may be done to simplify and improve the relationship between man, the operator, and the machine he controls. It will show the concepts and methods being employed in this continuing effort.

On April nine, nineteen fifty-three, at the request of the United States Navy, some two-hundred-fifty representatives of the aircraft and instrument manufacturing industries and from the Army, Navy, Marine Corps and Air Force, attended a conference in Washington, D.C. It was disclosed that the Office of Naval Research and the Bureau of Aeronautics had initiated an industry-wide program aimed at the development of an integrated presentation of flight data. It was believed by the Navy, the necessary coordination could best be performed by an agency which would have design responsibility for the total system. Invitations had been forwarded to qualified prime contractors in the fixed and rotary wing fields.

The Douglas Aircraft Company's El Segundo Division was selected as coordinator for the fixed wing portion of the program. Shortly after this, the Army joined the Navy in sponsoring the program. (Fig. 1.)

Later, as a result of promising work in the fixed wing field, the rotary wing phase of the program was initiated and the Bell Helicopter Corporation was chosen as coordinator.

At the outset, it was recognized that man has basic limitations. Man-made machines will never duplicate man's brain and his ability to assume command in emergencies, yet today's high performance vehicles confront the operator with complex mechanisms and instrumentation. (Fig. 2.) His display panel presents an array of instruments which cannot be read as an entire unit. The operator must scan, choose and interpret numerous bits of information before he can initiate the appropriate control responses in the performance of his mission, causing undue interpretation and integration by the operator and resulting, many times, in errors, disorientation, accidents, aborted missions and deterioration of morale.

Taking the aircraft as an example, attempts have been made to align instruments (Fig. 3) to reduce the pilot's task, and attempts have been made to combine instruments, (Fig. 4) but still the problem persists. An entirely new concept of instrument presentation would have to be conceived. Without demanding maximum mental interpretation, translation and integration, the presentation should give the pilot direct

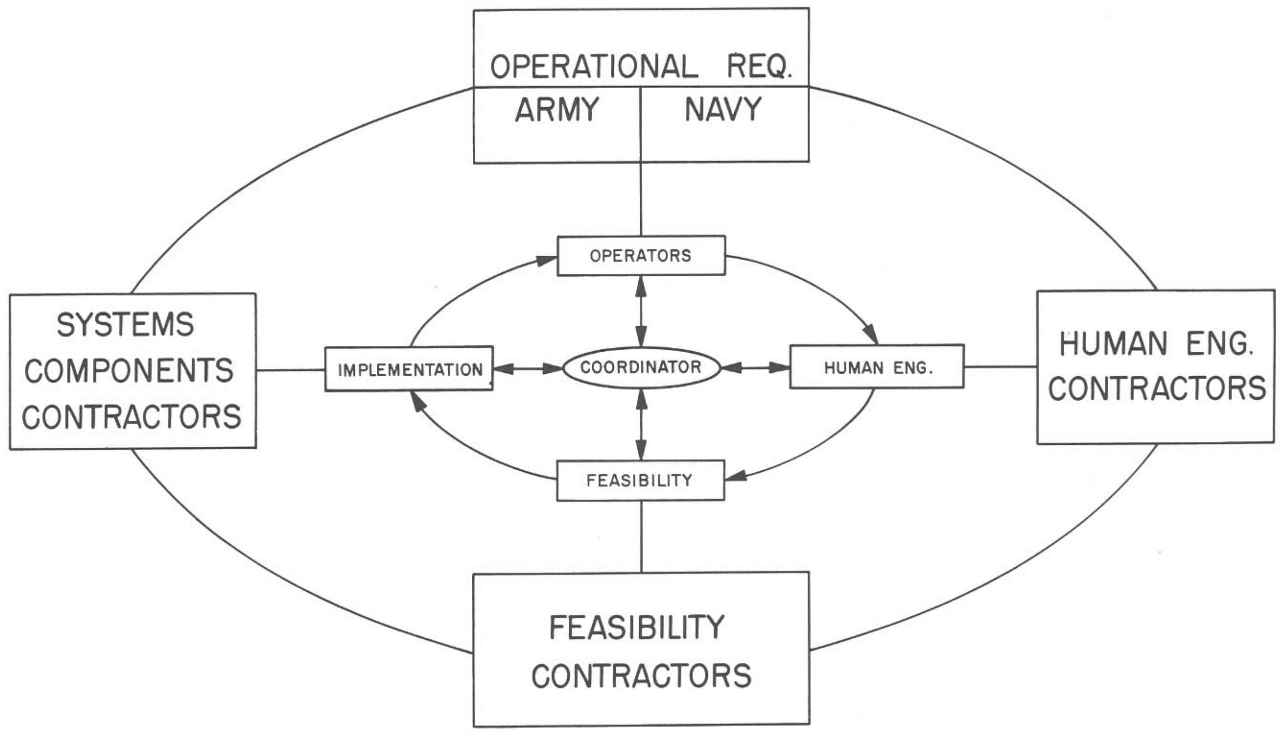
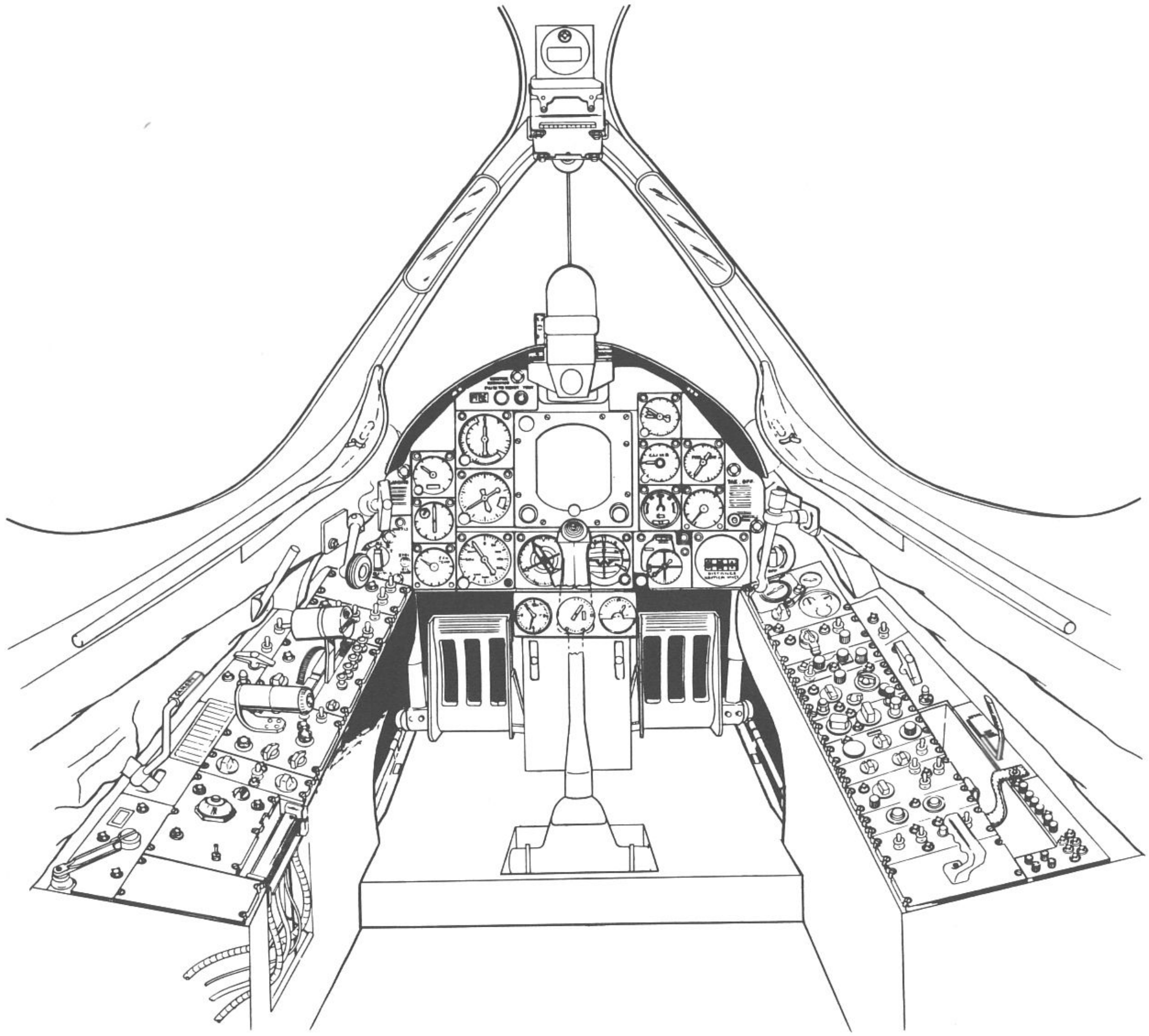

OPERATIONAL REQ.
ARMY
NAVY
OPERATORS
SYSTEMS COMPONENTS CONTRACTORS
IMPLEMENTATION
COORDINATOR
HUMAN ENG.
HUMAN ENG. CONTRACTORS
FEASIBILITY
FEASIBILITY CONTRACTORS

FIGURE 1



TODAY'S COCKPIT

FIGURE 2

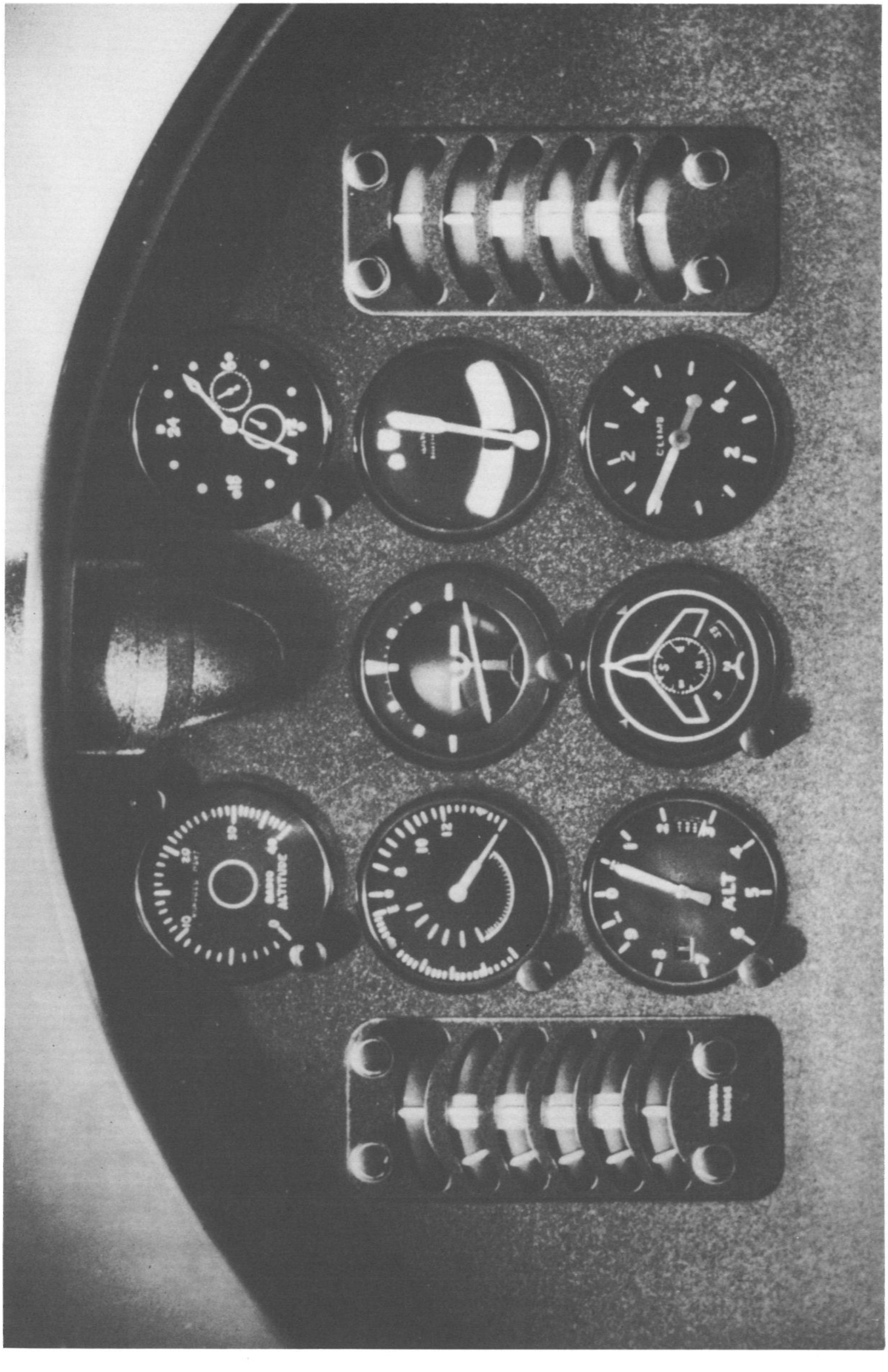


FIGURE 3

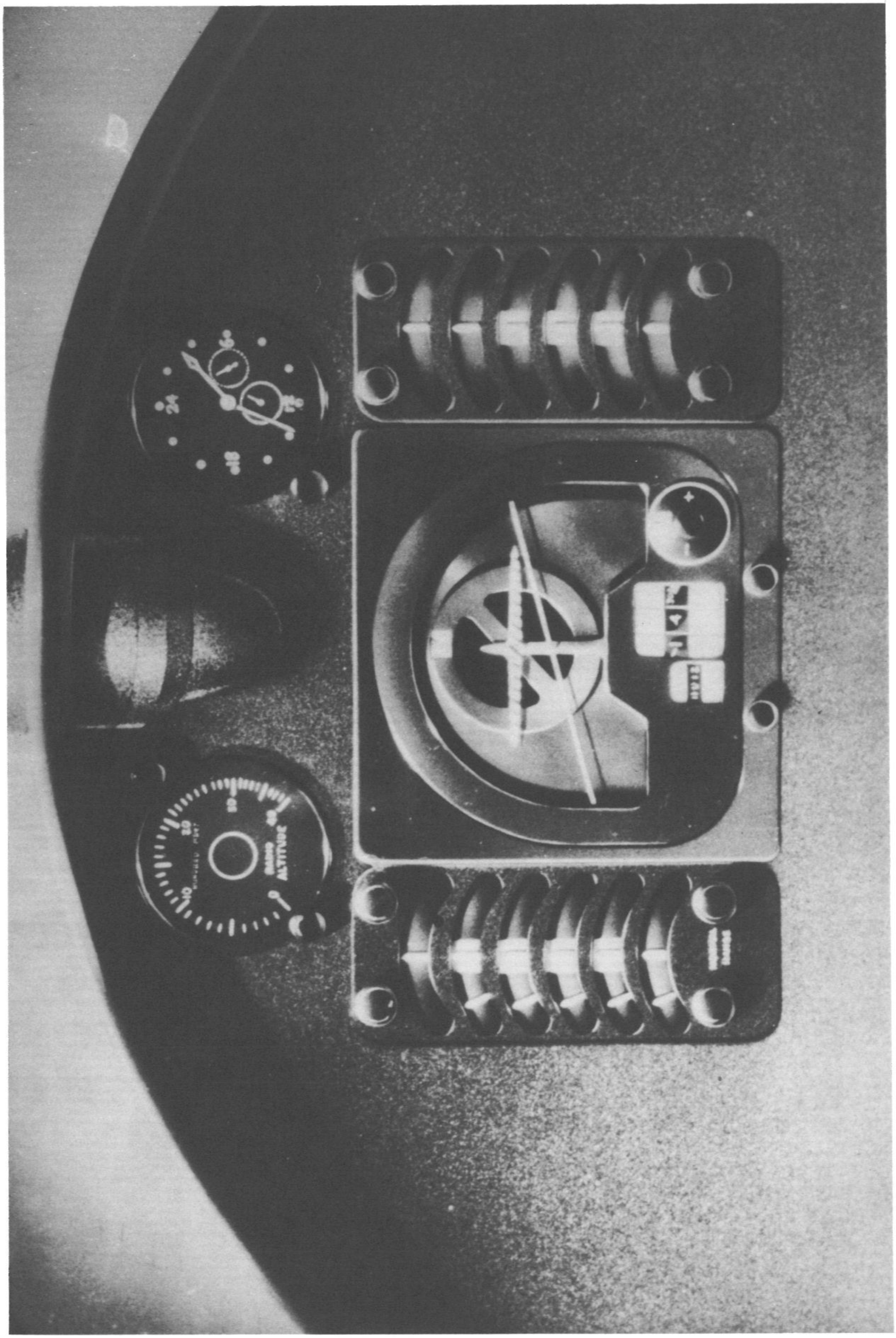


FIGURE 4

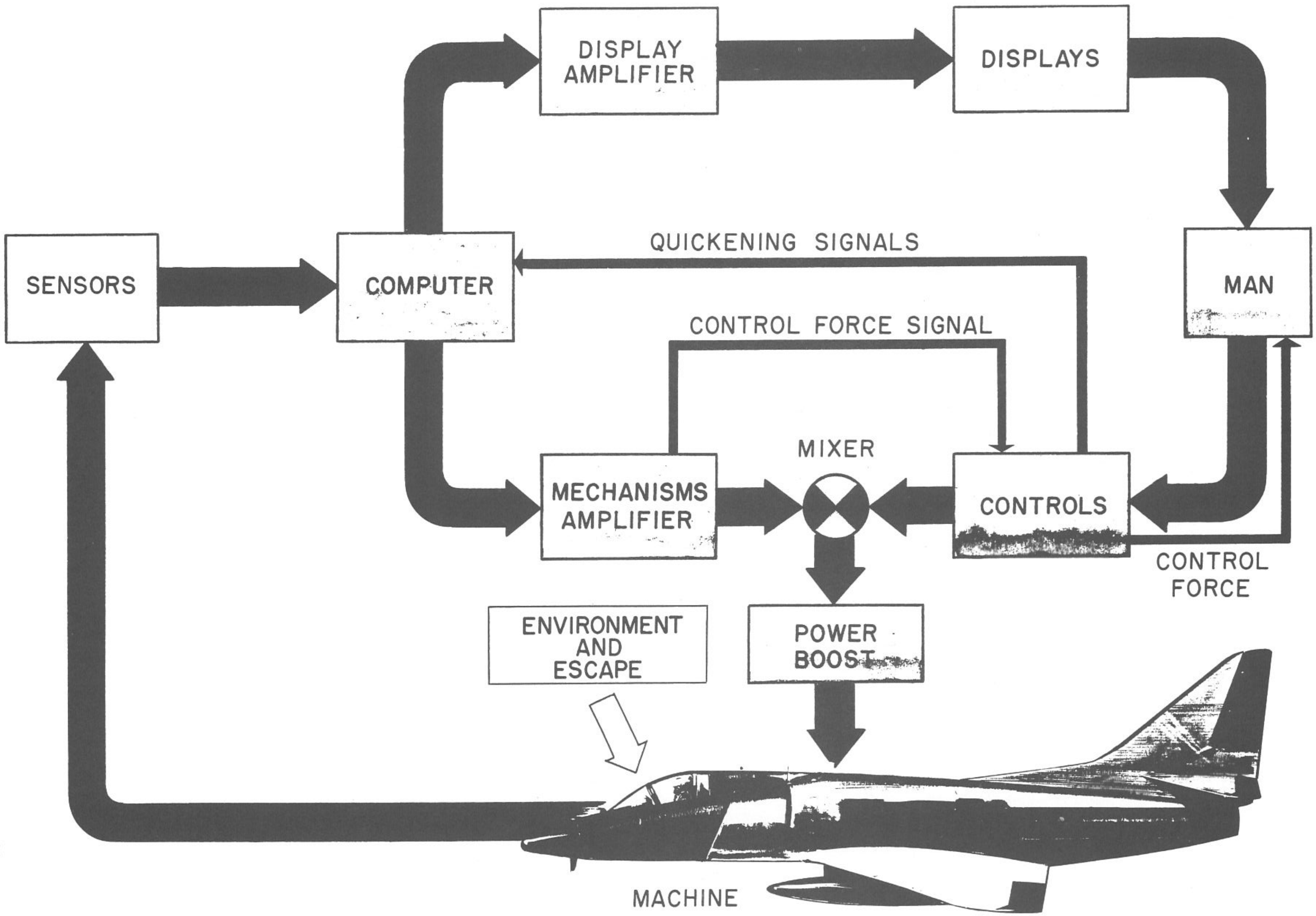
responses to the questions he needs answered. Man will always remain a link in the system, whether aircraft, missile, submarine, ship, or ground vehicle. Therefore, the initial step in the program must be to create the machine around the man. (Fig. 5)

Under the man-machine approach, the operator would be concerned only with those tasks he performs most efficiently. To this end, man must have available to him certain basic information. His immediate surroundings must conform with the physiological limitations of his body. One of the building blocks of the generalized system is that of the sensors, or data gathering elements. Constituted of these fundamental groups: electromagnetic, temperature, force, inertial, physical quantity and geometry, the sensors would send information to a central computer, which would select information necessary for operator displays and control of the vehicle. Data processing and memory storage for the entire system would be integrated into a single device, resulting, in greater reliability, major savings in weight, space and power consumption. The computer would feed information into display, amplifying equipment which would drive the operator's display to present data fulfilling information requirements...thus enabling the operator to take appropriate action for the situation. Simultaneously, the computer provides information to satisfy the requirement of the automatic portion of the control loop. The combined control signals are amplified and fed into the machine. It is readily seen that neglect of either man or machine requirements will compromise the overall system efficiency.

The programs' initial conception primarily concerned aircraft, but it soon became evident the ultimate goals would be applicable to all man-made vehicles... to helicopters, to missiles, to submarines, in tanks, or in surface ships.

As the application of the long range program expanded, it became apparent that new methods had to be established if major progress was to be made. To establish effective direction of the diverse scientific and engineering talents involved, a suitable information flow structure was created.

The users of these systems develop operational requirements from their experience in the natural world. These requirements are divided into two groups: Information requirements necessary to the operator in accomplishment of his mission, and -- machine or performance requirements to be used by the coordinator in directing the overall team effort. Since the



MAN MACHINE SYSTEM

FIGURE 5

Man-machine system must meet these operational requirements, the information requirements for the man must be established by questioning the operators who control the system.

Conducted by the coordinator for each phase of operation, the questioning is designed to differentiate the fundamental requirements needed by all operators, from those based upon unsubstantiated opinion.

The requirements are transmitted by the coordinator, along with system performance requirements, to human factors analysts who determine what functions are best performed by man in the total system, and the best displays and controls to enable man to perform those tasks. The investigations seek an optimum solution for the man and are not confined by possible limitations in electronic and mechanical equipment.

Display and control requirements determined by the human engineering team are used in conjunction with the overall system performance requirements as a basis for studies by engineering physicists, to determine what data must be sensed, the relationship which must exist between sensors, display and machine control signals, and whether these requirements can be met with techniques existing, or developmental techniques, or techniques still in the research stage. In addition, the research and development results needed before the system can be constructed, must be outlined. (Fig. 6)

The results of the feasibility studies are issued to industry for the development of specific elements in the man-machine loop, and for required research. The research results constitute advance in the state of the art to be considered by future feasibility studies.

The sub-systems and components as developed, are integrated into operable systems to be evaluated by the operators working with the coordinator. Objective tests and evaluations are performed to determine whether system and information requirements have been met. The tests result in recommendations to the operating activity procuring agencies for production development and also provide new data for further human engineering studies.

In following a small portion of the total operational requirements through the implementation system, we can witness how the interaction of the various team groups brings about the integration of this portion into a flight system.

LONG RANGE FEASIBILITY STUDY SUMMARY CONTRACT NONR 1076 (00)

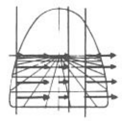
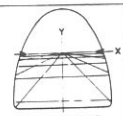
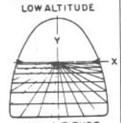
PHASE OF FLIGHT	PILOT INFORMATION REQUIREMENTS	HUMAN ENGINEERING DISPLAY REQUIREMENTS		DISPLAY PHYSICAL REQUIREMENTS AND MEDIUM	DATA TO BE SENSED	DISPLAY VISUAL CHANGE	COMPUTATION	TRANSMISSION LINK	DISPLAY CONVERSION CIRCUITRY	SYSTEMS	SENSORS
		CUES	INTEGRATION								
NORMAL FLIGHT	• SPATIAL ORIENTATION • HEADING	• INTERNAL REFERENCE • EXTERNAL REFERENCE • TEXTURE GRADIENT • MOTION PARALLAX • LINEAR PERSPECTIVE	• CONTACT ANALOG	ALSO SEE NAVIGATION	ANGLE BETWEEN AIRCRAFT LONGITUDINAL AXIS AND REFERENCE HEADING (TRUE NORTH OR GRID REFERENCE) IN A PLANE TANGENT TO THE EARTH SURFACE DIRECTLY BENEATH AIRCRAFT	UNIFORM MOTION OF DISPLAY FIELD ACROSS DISPLAY MEDIUM 	$\frac{\partial y}{\partial \theta} = 0$ $\frac{\partial x}{\partial \theta} = \frac{x^2 + K_o^2 \sec^2 \alpha}{K_o \sec \alpha}$	•360° INFORMATION R & D REQUIRED (DAC 7447628) •VIDEO SCAN R & D REQUIRED	• SCREEN SWEEP INTENSITY MODULATION • CODED IMAGE STORAGE OR GENERATION R & D REQUIRED		TRUE NORTH OR REFERENCE HEADING STABLE REFERENCE (DAC 7553925)
	•ALTITUDE & RATE OF CLIMB SEE ALSO: NAVIGATION • ALTITUDE			• HORIZONTAL BAROMETRIC PLANES EVERY, 5000', CODED • MINIMUM SAFE ALTITUDE PLANE CODED WITH RANDOM CIRCLES •DISPLAY MEDIUM SAME AS FOR PREVIOUS NORMAL FLIGHT REQUIREMENTS •SEA LEVEL PLANE OR GROUND DATUM 1000' SQUARES WITH CIRCLES OR DOTS LOCATED 20' APART •OTHER PLANES HAVE GRID, POSSIBLY CODED BY ALTITUDE	ALTITUDE ABOVE MEAN TERRAIN AND/OR PRESSURE ALTITUDE	 LOW ALTITUDE  HIGH ALTITUDE TEXTURE GRADIENT BECOMES LESS DENSE AT HORIZON MORE DENSE AT TUBE BASE FOR INCREASE IN ALTITUDE; TEXTURE ELEMENTS DECREASE IN SIZE WITH ALTITUDE INCREASE UP TO 5000', AT WHICH POINT ALTITUDE DISPLAYED RETURNS TO ZERO & CODE CHANGES  CODED ALTITUDE DISPLAYS 	$\frac{\partial y}{\partial h} = \frac{1}{2HK_o}\left[(y^2 - K_o^2)\sin 2\alpha + 2yK_o\cos\alpha\right]$ $\frac{\partial x}{\partial h} = \frac{x \sin\alpha}{HK_o}\left[y\cos\alpha - K_o \sin\alpha\right]$ H = DISTANCE FROM AIRCRAFT TO DISPLAYED PLANE	R & D REQUIRED IN THESE AREAS •(TERRAIN) PULSE TIME DELAY OR PHASE SHIFT •(BARO.) VARIABLE INDUCTION, RESISTANCE, OR CAPACITANCE TRANSDUCER • ACCELERATION VARIABLE R, L, OR C • VIDEO SCAN R & D REQUIRED	•SCREEN SWEEP INTENSITY MODULATION •CODED IMAGE STORAGE OR GENERATION	•DAC 7540324 •CENTRAL COMPUTER GIVES "H" SIGNAL TO DISPLAY GENERATOR •VERTICAL ACCELERATION IF REQUIRED. IMPORTANT TO ELIMINATE LAG IN P_o SYSTEM	•ELECTRO-MAGNETIC DAC 7554808 •PRESSURE (DAC 7447901) •VERTICAL ACCELERATION ON STABLE PLATFORM (DAC 7553925)

FIGURE 6

Operational activities determined that the majority of combat missions can be broken down into a number of phases such as take-off and climb, rendezvous, cruise and navigation, strike, traffic control and landing. (Fig. 7) Although, for a number of important purposes, it has been found that all of these phases had the same requirements, it was necessary for the coordinator to question the pilots, on each phase, to establish whether significant differences existed.

To uncover the fundamental requirements, it was found that a unique method of interrogation had to be utilized. It was found necessary to continue to ask "why" after each statement by the pilot, until the interrogator's "why" questioned the validity of the objective, or until the answer could stand unchallenged. It was found, in this instance, that among the pilot's primary needs was not a compass, not a vertical gyro, but his orientation with respect to the ground plane ... spatial orientation.

This method of interrogation was employed with a sizeable number of pilots to determine the basic information required for each flight phase, until a list of information requirements was unequivocally established. Since the program's inception, no major change has been found necessary in this list, demonstrating that this method of questioning reveals fundamental information requirements.

The list of information requirements was distributed to a group of human engineers, each having been assigned specific phases of flight to study. Their task was to determine the methods by which the information would best be displayed for the pilot to operate his aircraft with maximum efficiency and minimum mental interpretation, resulting in minimum training requirements.

To determine the effectiveness of the display, it was necessary to establish a yardstick for comparison. Initially, no attempt was made to design an optimum system, but rather to design a system which would be adequate to permit the pilot to operate his aircraft under instrument conditions as effectively as under ideal contact conditions. This would then give a point of reference from which to continue the optimum display and control system determinations.

Since pilots are generally capable of operating quite effectively under ideal contact conditions, the human engineers had to determine how the visual world provided information to the information requirements. In other words, what factors in

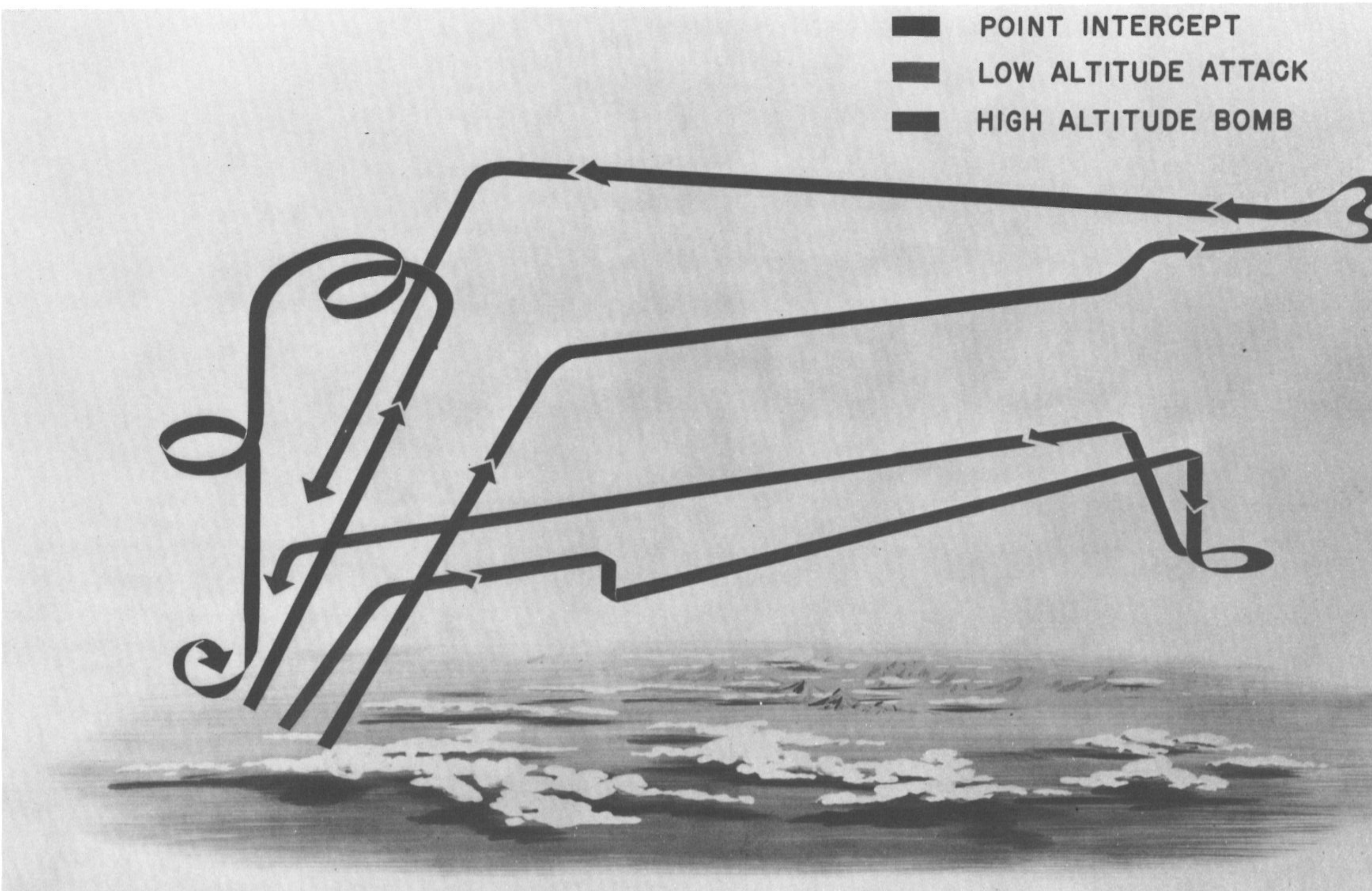


FIGURE 7 TYPICAL FLIGHT PROFILES

the visual world enable the pilot to operate his aircraft. It was established early in the study that there were three basic categories of information required throughout all phases of flight. Orientation information, or "Where am I and what am I doing?" Director information, or "What should I do and when?" and quantitative information, or "How am I doing?"

A pilot judges his relationship to space and time under contact conditions, primarily by reference to visual cues. One important visual cue was found to be an internal reference, which permits the pilot to regard himself and his aircraft as a single unit. Such a reference normally is available to the pilot in the form of a windshield. (Fig. 8) A second important visual cue is external reference. To the pilot, one of the most common external references is the horizon. (Fig. 9) It enables him to determine the relationship of his aircraft to external objects. This information alone, quite often gives rise to misinterpretations. Parallel lines, apparently converging represent linear perspective, (Fig. 10) helping the pilot to judge angular and altitude changes as witnessed in a dive. The texture of a reference surface is used by the pilot to determine slant of the surface, altitude and distance. (Fig. 11) This powerful visual cue is sufficient in itself to establish orientation without reference to the horizon. A textured surface representing the sky, composed of a distinctly different pattern from the ground pattern, provides orientation when the ground plane is not available. (Fig. 12) In air-to-air orientation, the closer of two similar aircraft would appear to be larger, indicating size is also an important cue. (Fig. 13) Movement over the surface results in an apparent distortion of the visual field, and this is known as motion parallax. Motion parallax provides a compelling cue to distance, speed, and direction of motion.

By combining the visual cues abstracted from the real world, an artificial model can be created which for purposes of orientation is perceptibly equivalent to the real world. A display created from this model may be called a contact analogue.

The real world does not, in general, contain command or director information. However, since mission objectives require operations about all 3 axes, such commands may be expressed in terms of desired flight path in space. Director information could be achieved in a manner compatible with cues for basic orientation. With the addition of such a flight path to the contact analogue deviations from the command course and altitude become immediately apparent. (Figs. 14 and 15) Paths may be constructed for various maneuvers such as traffic control,

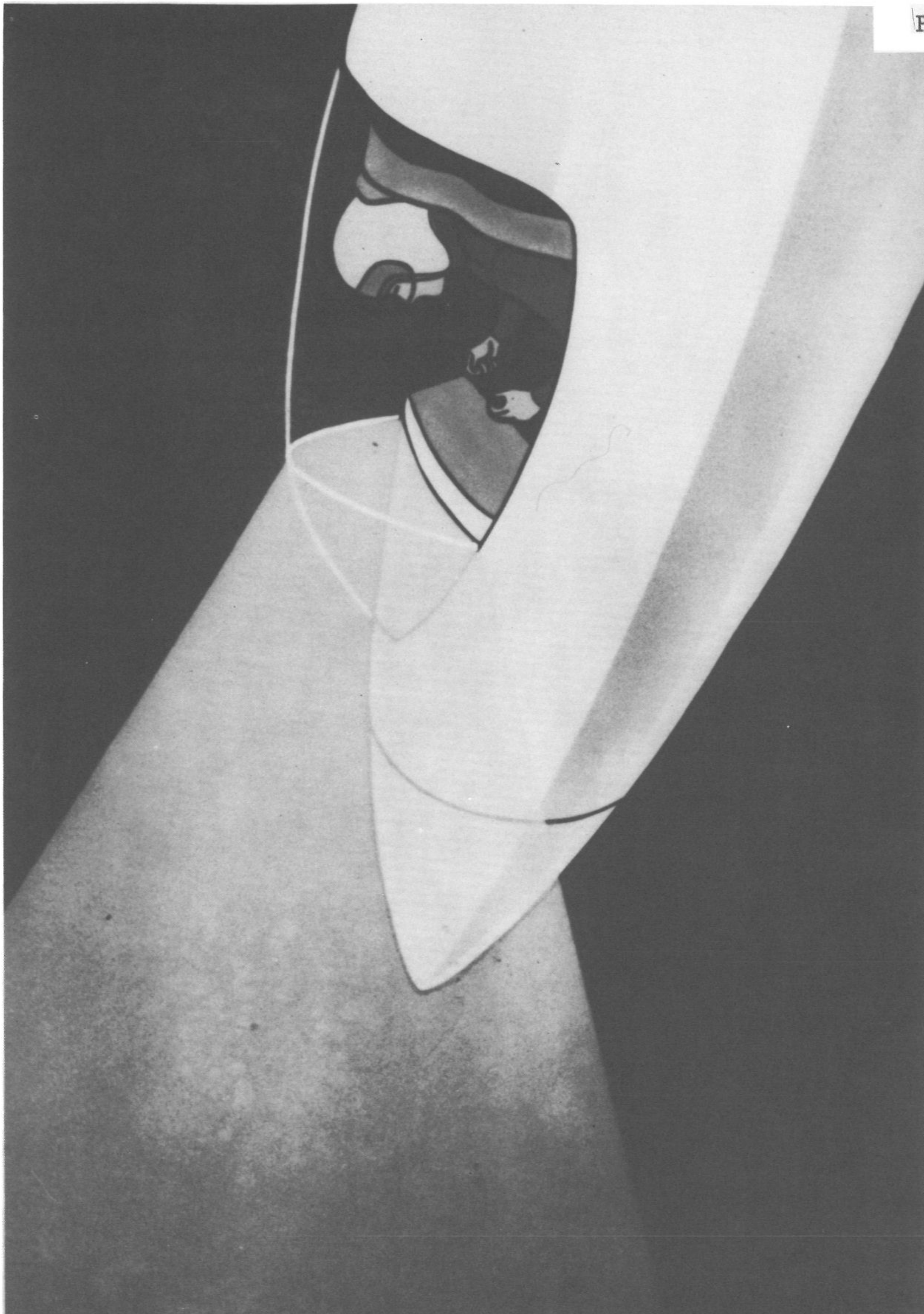


FIGURE 8

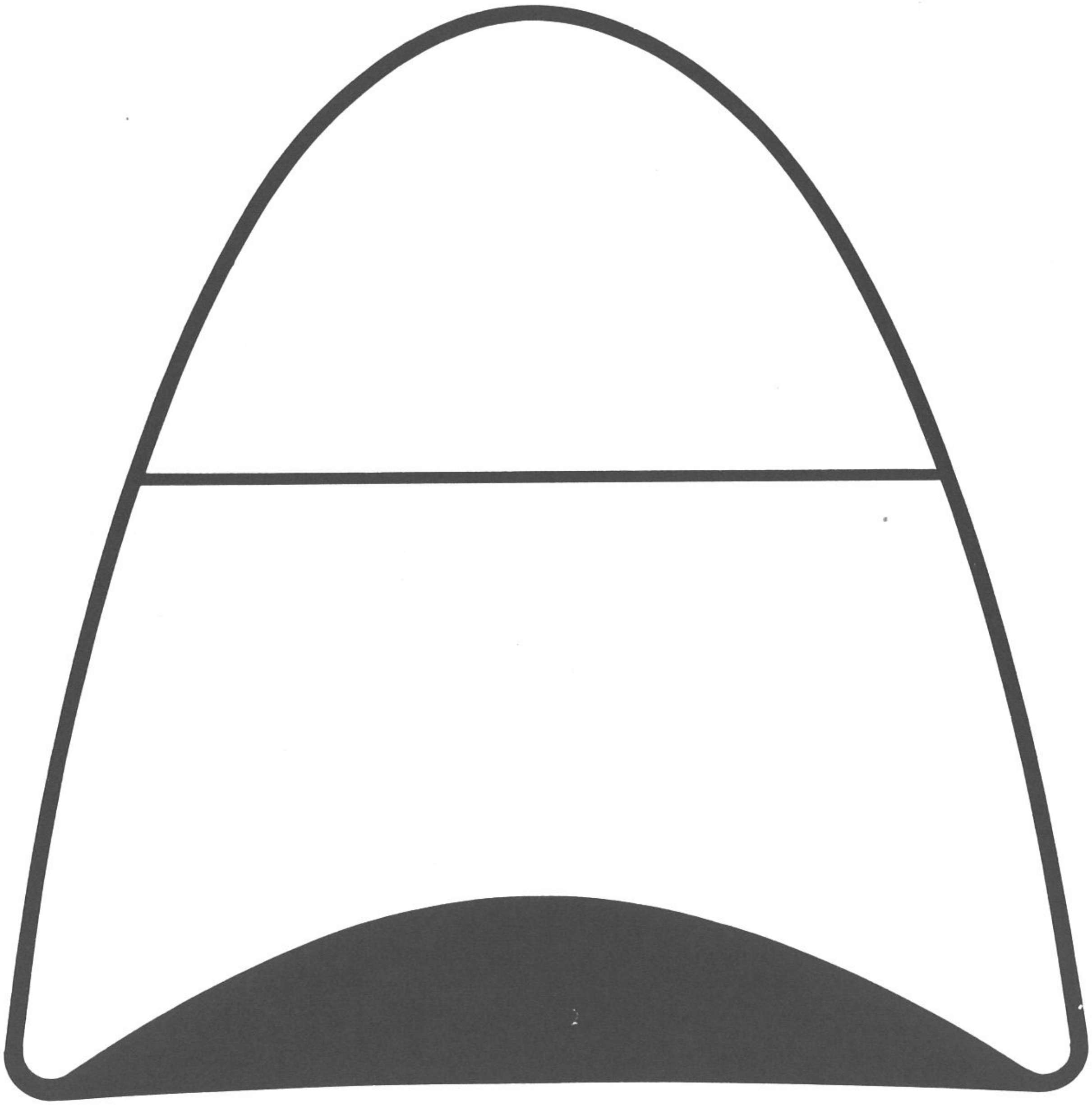


FIGURE 9

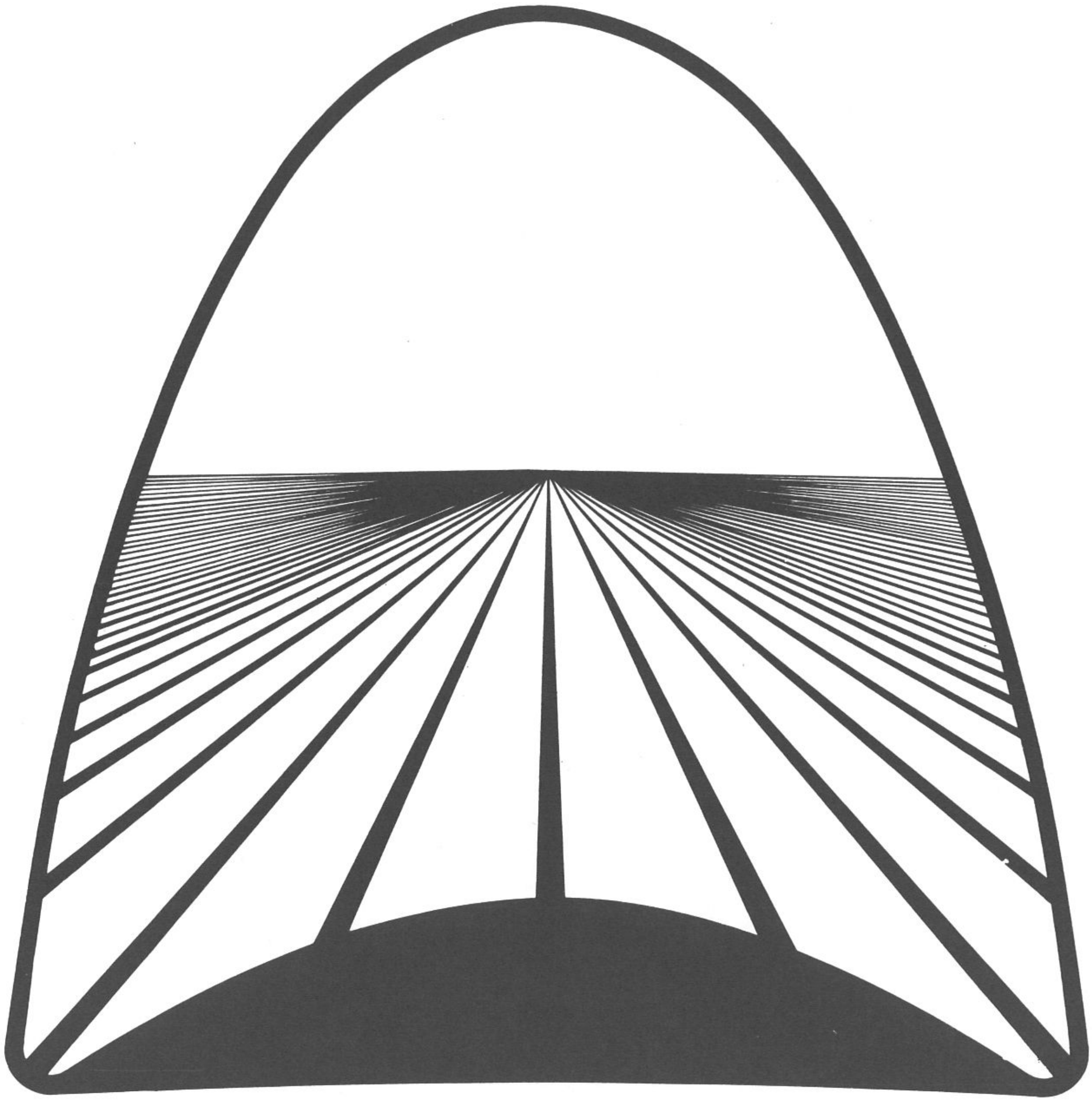


FIGURE 10

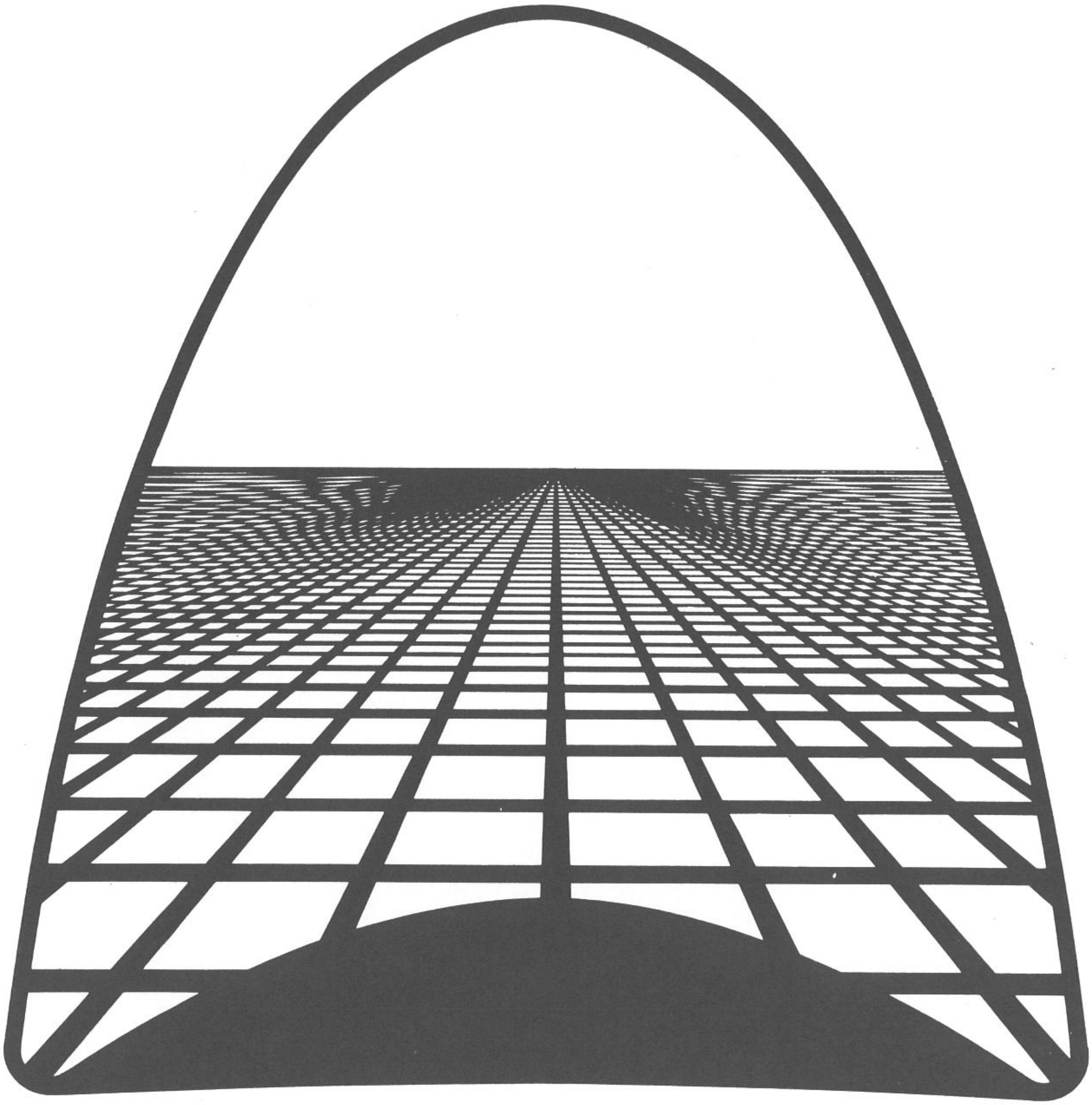


FIGURE 11

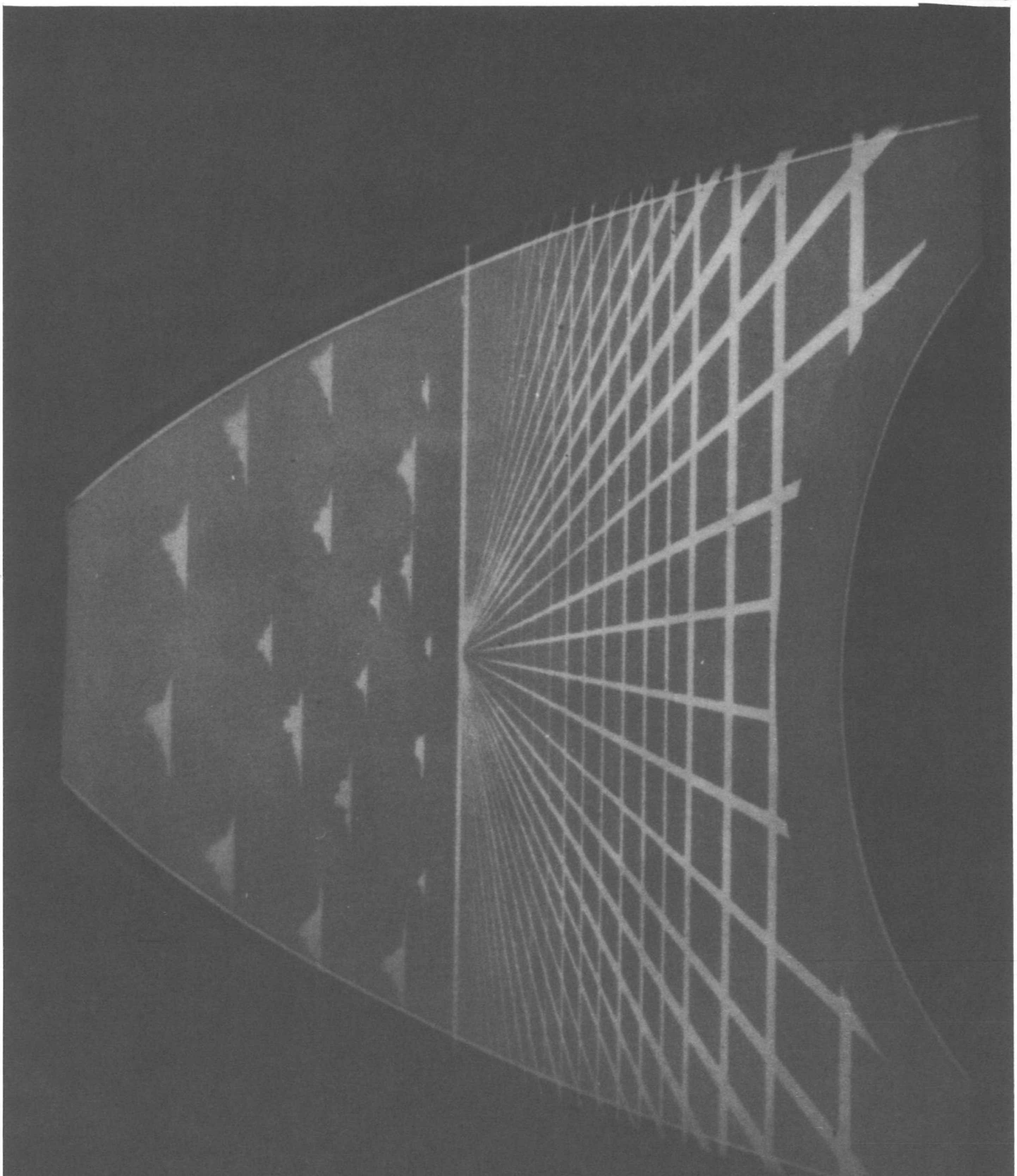


FIGURE 12

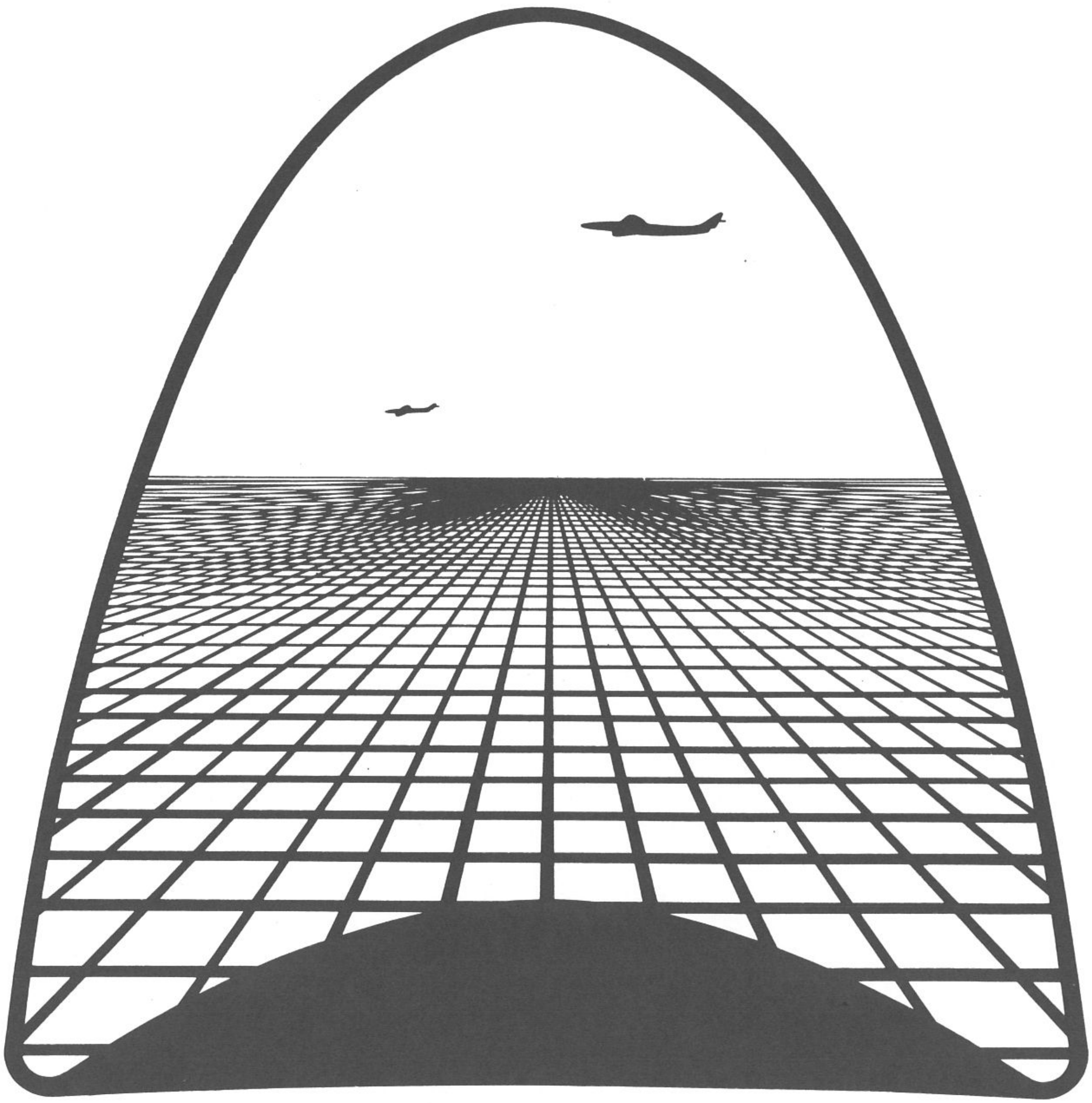


FIGURE 13

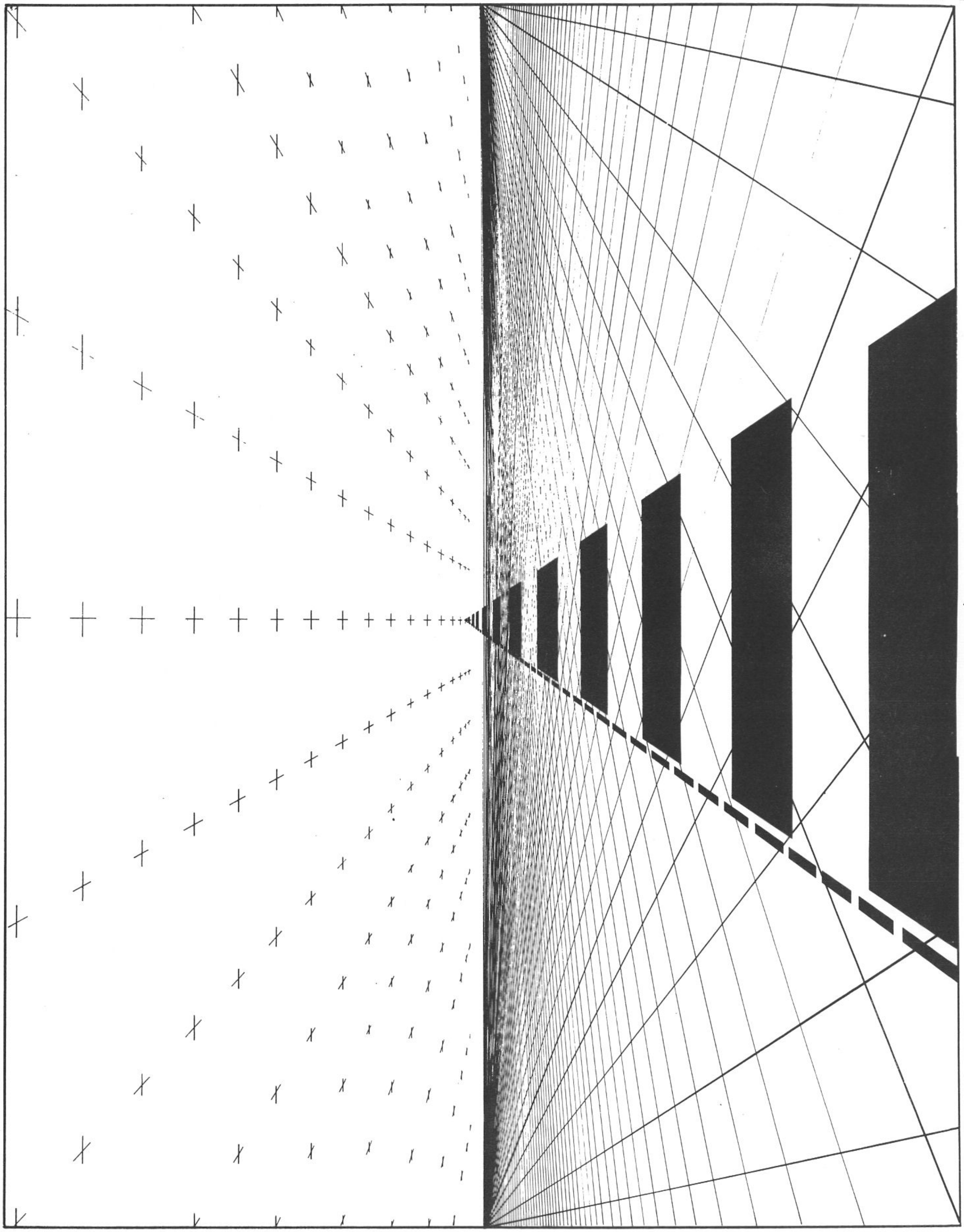


FIGURE 14

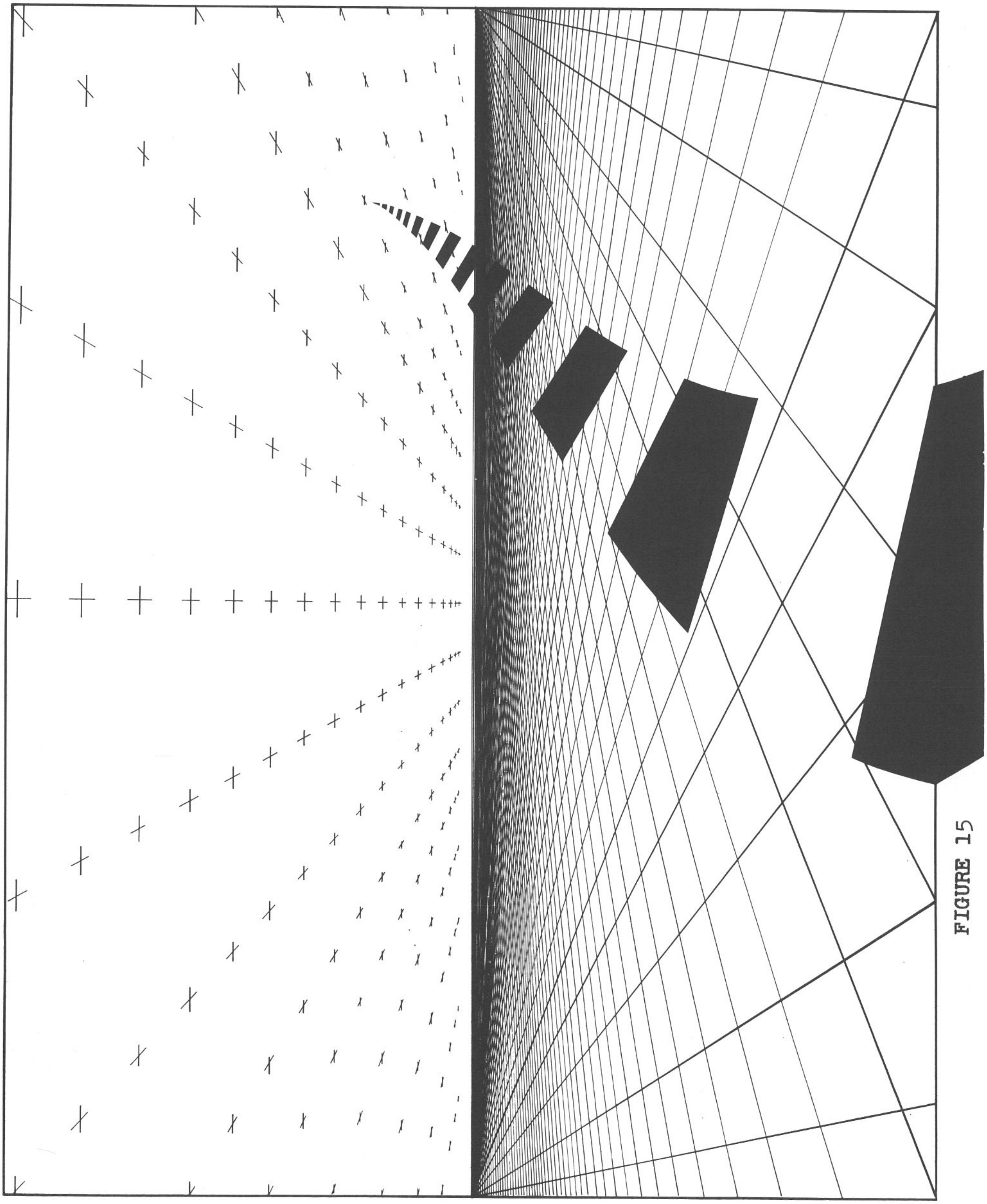


FIGURE 15

rendezvous, strike, climb out, roll and landing. It is not necessary for the contact analogue to present a surface ruled into a regular grid. It is believed that for some cases the optime pattern might take other forms. (Fig. 16 and 17)

In addition to the contact analogue, a display representing information on an appropriate scale is required to fulfill navigation, cruise, and tactical planning. Information concerning local geography, present position and heading, targets, destinations, flight plan, fuel range remaining and other points of tactical interest, could be integrated into such a display. (Fig. 18) The requirements for the tactical situation display and additional quantitative information have yet to be fully determined, but work is in progress in these areas.

The detailed display requirements for the contact analogue and situation display having been established were distributed by the coordinator in the form of specifications, to a number of companies with broad experience in the field of electronic systems and components development.

Their task was to determine not how to design specific equipment to produce the desired display, but rather to determine the system's technical requirements for display, data processing and sensing. Here again, as in previous studies, the same approach was taken to establish fundamentals by employing the technique of asking why until the basic requirements were evolved.

The technical requirements group determined in this example the need for development of a thin, transparent display medium. Additional examination of system and aircraft requirements indicated that one possible solution might be the development of a thin, transparent cathode-ray tube. (Fig. 19)

Studies of the equations involved in the changes within the display, established the various physical phenomena which had to be sensed, the computer requirements, and the techniques applicable for the generation of the display.

Investigation of phenomena capable of meeting these requirements, established the possibility of developing specific sensors.

The results of the feasibility studies indicated the need for development of circuit concepts, research in materials and fabrication processes necessary to meet the requirements of the total system.

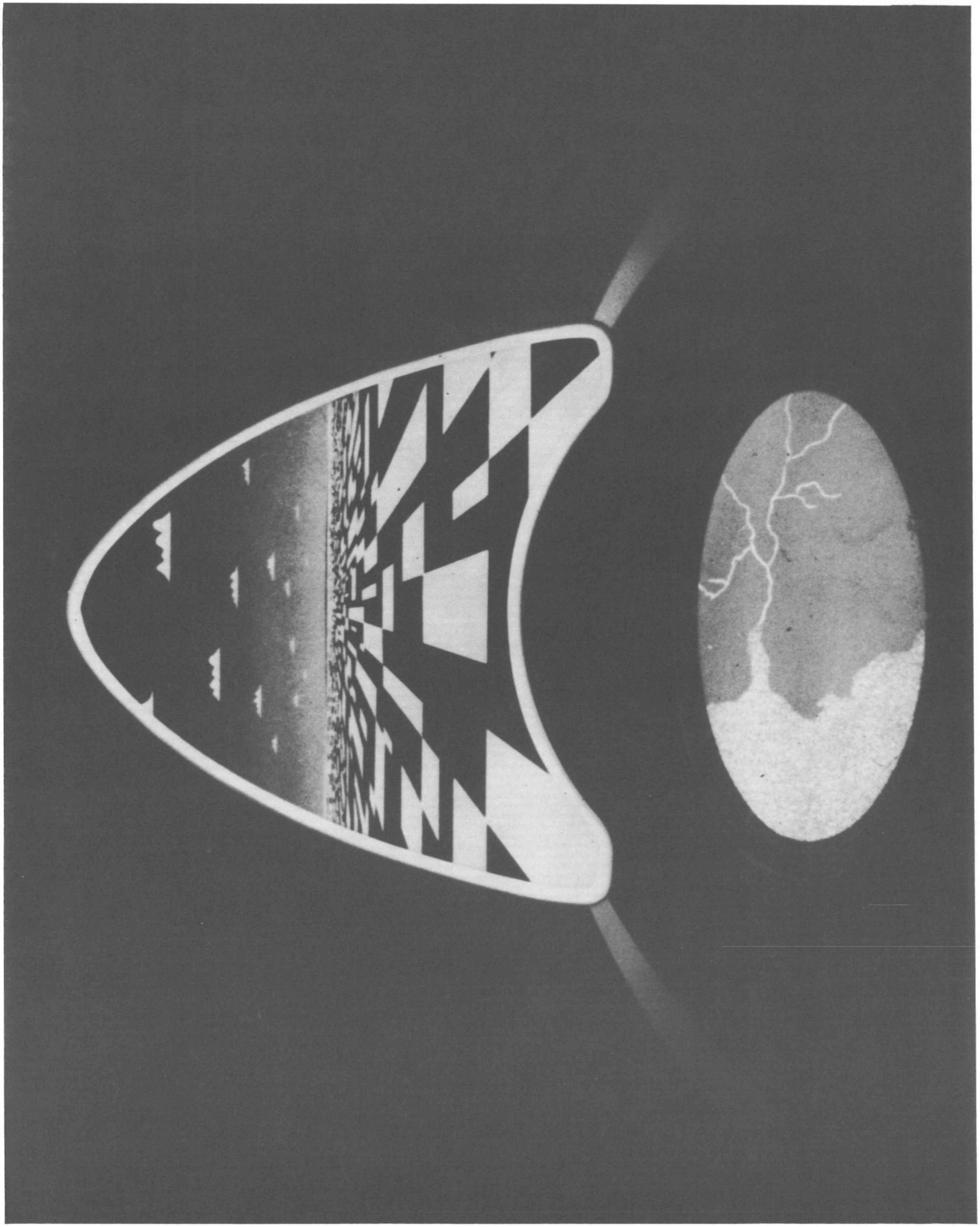


FIGURE 16

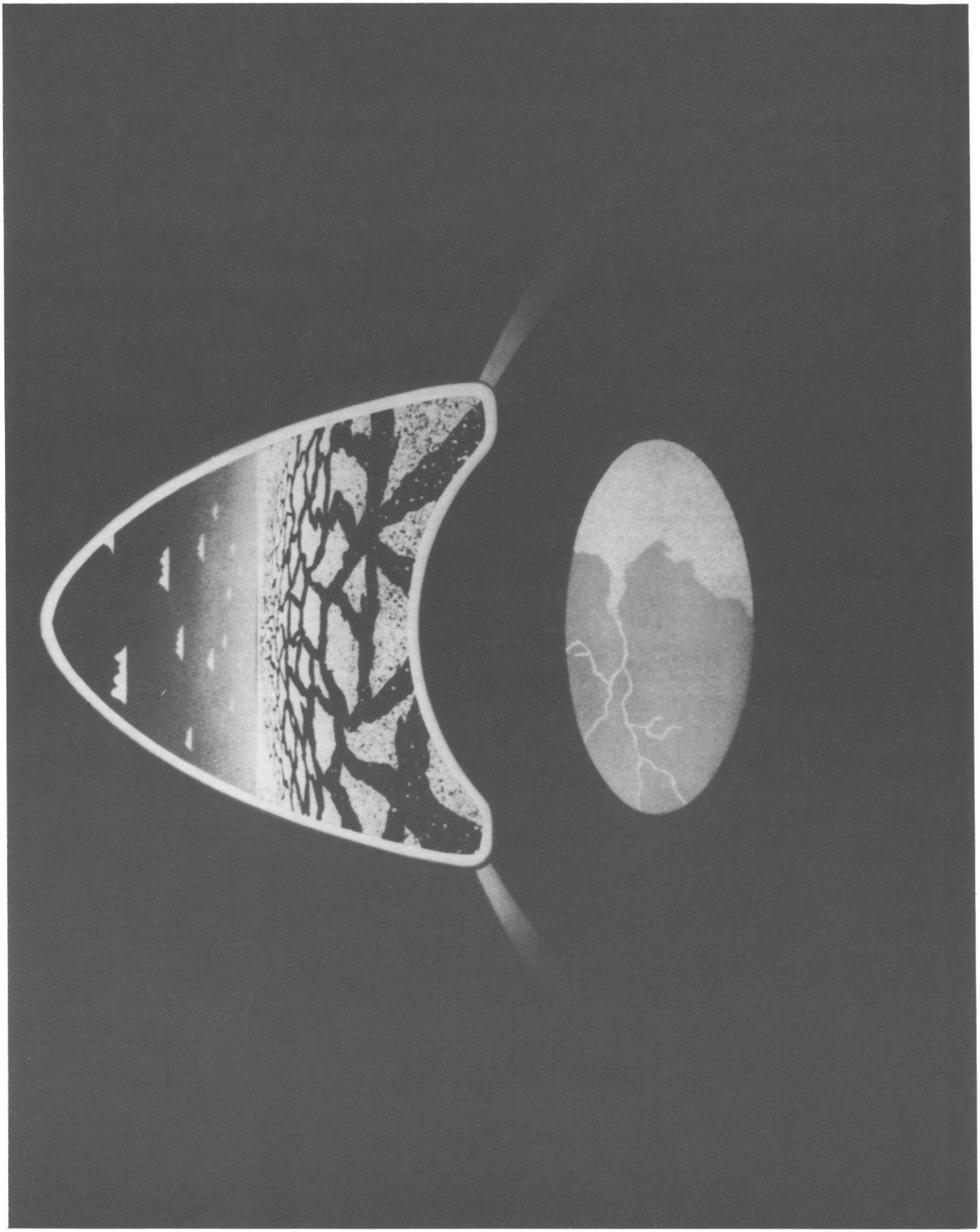


FIGURE 17

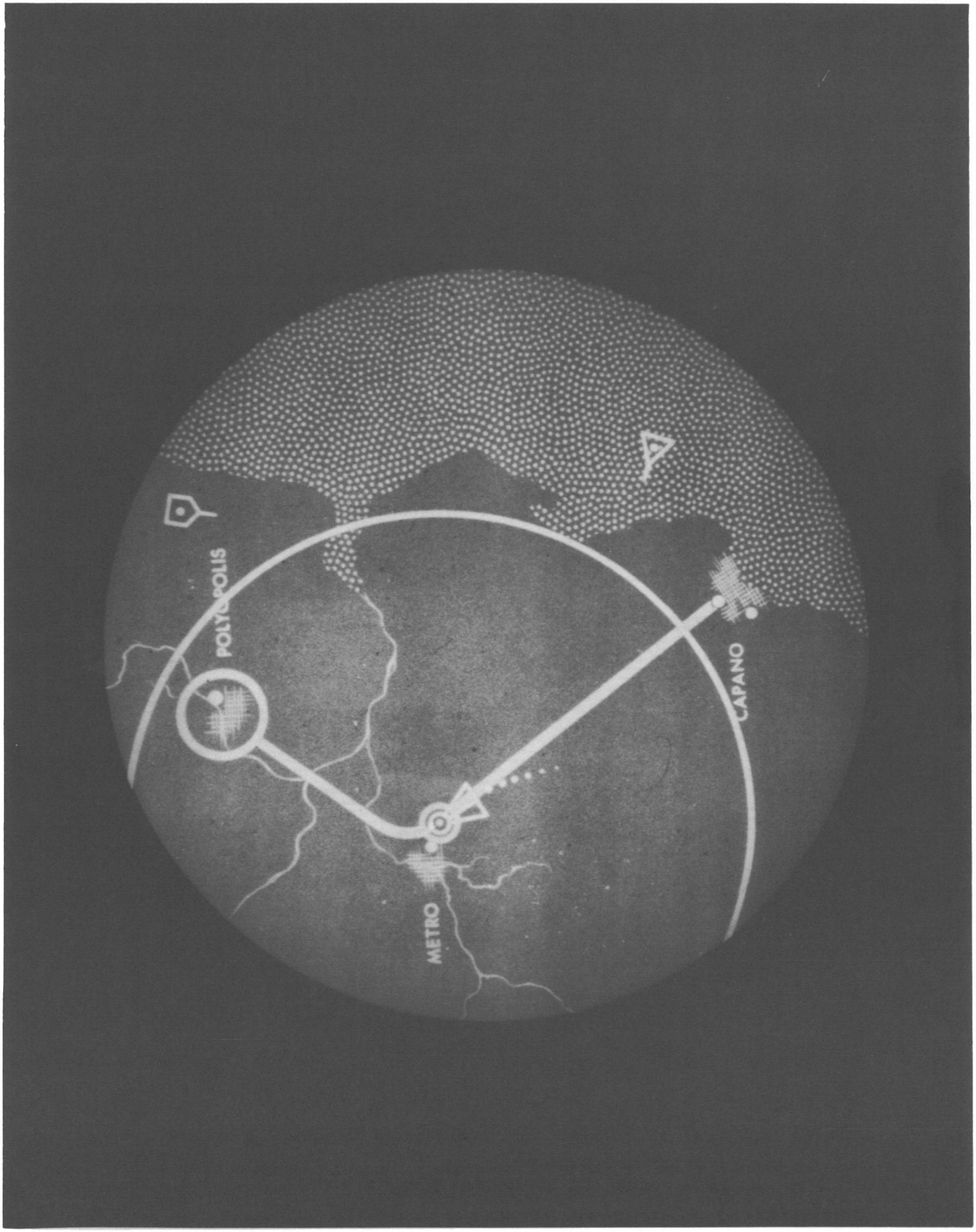


FIGURE 18

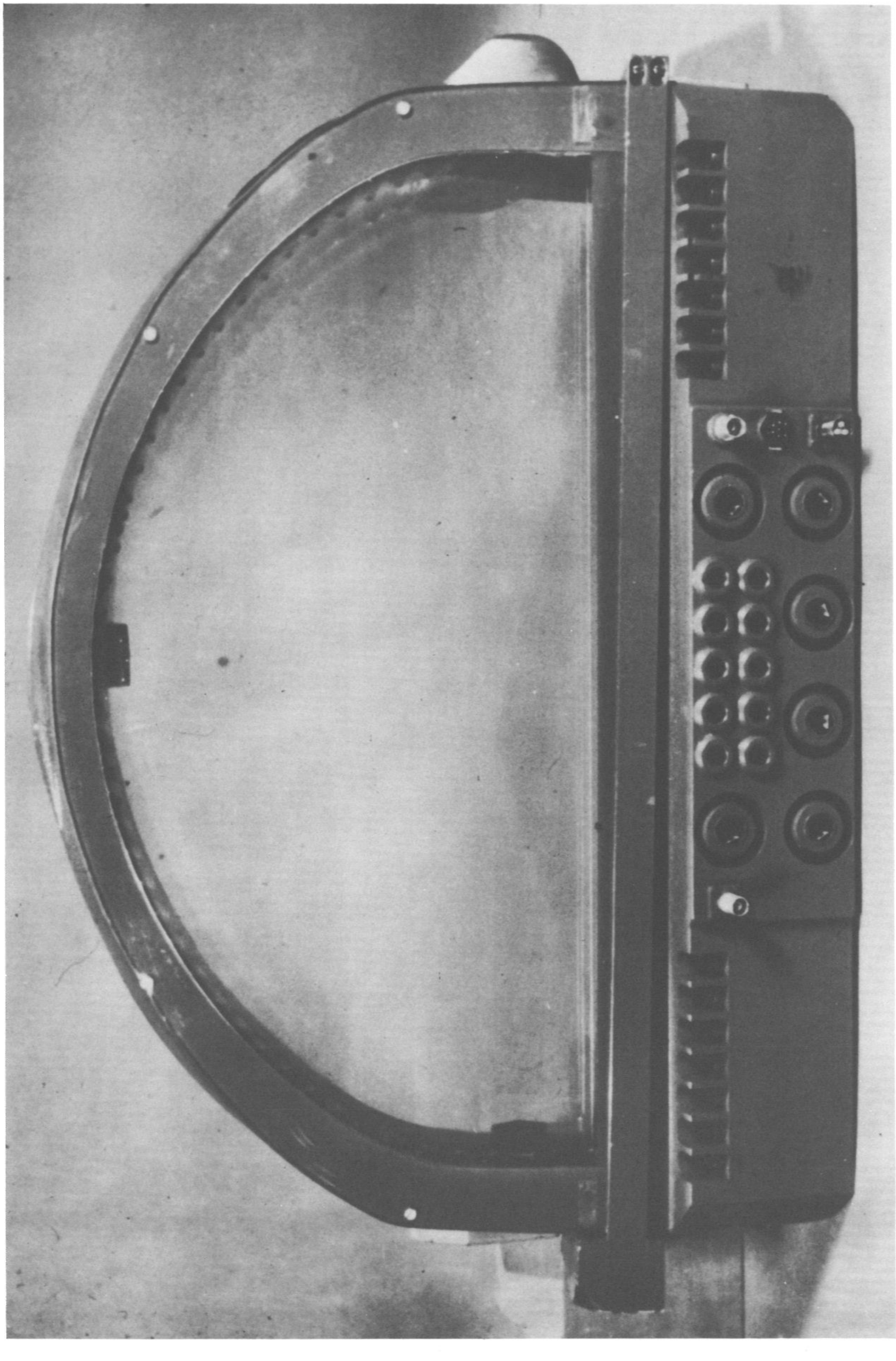


FIGURE 19

Contracts for the development of sensors, computing elements and display media, were awarded as these requirements were established in the fixed and rotary wing aircraft programs. The search continued in every case to find fundamental solutions rather than partial solutions.

These have been the concepts and the methods employed in the continuing effort to improve the relationship between man and the machine he controls. The Army-Navy Instrumentation Program, combining the techniques, facilities and investigative skills of the aircraft and instrument manufacturers, is moving toward the satisfactory completion of this program by adhering to the team approach method with uninhibited thinking.

In summation, the program embodies optimum presentation and control for the man-machine system. Applicable not just to aircraft but to missiles, ships, submarines, tanks. Industry-wide participation, a completely integrated system reducing weight, size, maintenance and training time, increased reliability, a new approach method with the optimum use of talents, a program based on objective considerations with the elimination of opinions, and development proceeding from logical requirements derived from fundamental considerations rather than from undirected invention.

In the Army-Navy Instrumentation Program, the problem is stated before a solution is attempted.